HAYNES International

Our Aerospace Alloys and Applications

Aerospace Alloys and Applications

For over 113 years, we have been a global leader in the development, manufacturing, and delivery of high-performance alloys for mission-critical applications.

Our aerospace legacy spans from the earliest jet engines to today's most advanced space exploration programs. Our materials are developed into components across nearly every commercial aircraft platform, numerous military systems, and cutting-edge space vehicles.

We are dedicated to delivering unmatched product quality, alloy & application expertise, and customer support to meet the evolving demands of the aerospace industry.

HAYNES® 292® alloy

HAYNES® 292® alloy is a new wrought, gamma-prime strengthened superalloy for high-temperature applications such as cases and rings used in aero and industrial gas turbine engines. This new alloy can be readily fabricated and welded and is expected to offer superior low-cycle fatigue (LCF) strength, creep strength, and oxidation resistance compared to Waspaloy and other wrought gamma-prime strengthened alloys.

HAYNES® 233® alloy

HAYNES® 233® alloy is a nickel-cobalt-chromium-molybdenum-aluminum alloy that has an exceptional oxidation resistance coupled with superior creep strength at temperatures up to 2100°F (1149°C), or higher – a combination of properties never before achieved in a readily fabricable alloy. Potential applications include hot gas components in aerospace and industrial gas turbines.

HAYNES® 244® alloy

HAYNES® 244® alloy is an age-hardenable, nickel-molybdenum-chromium-tungsten alloy with an extended operating temperature range to 1400°F (760°C). This alloy offers improved yield strength and creep rupture strength, versus HAYNES® 242® alloy, as well as a lower thermal expansion. Additionally, the alloy has excellent low-cycle fatigue and good oxidation resistance. The higher strength and lower thermal expansion provides better dimensional control, sealing, and containment characteristics for aero engine designers.

HAYNES® 282® alloy

HAYNES® 282® alloy is a wrought, gamma-prime strengthened superalloy developed for high-temperature structural applications, especially for those in aero and industrial gas turbine engines. It possesses a unique combination of creep strength, thermal stability, weldability, and fabricability not found in currently available commercial alloys. This alloy has excellent creep strength in the temperature range of 1200 to 1700°F (649° to 927°C), surpassing that of Waspaloy alloy and approaching that of R-41 alloy. The features of this alloy make it suitable for critical gas turbine applications, such as sheet fabrications, forged rings and cases, exhaust and nozzle structures, and other hot-gas-path components.

Note: Haynes has patented a newly developed alternative age-hardening treatment for 282® alloy for enhanced containment properties. For additional information, please contact Brandon Furr, +1 832-835-4681, BFurr@haynesintl.com.

HAYNES® 230® alloy

HAYNES® 230® alloy is a nickel-chromium-tungsten-molybdenum alloy that offers the best combination of high-temperature strength, resistance to oxidizing environments up to 2100°F (1149°C) for prolonged exposures, excellent long-term thermal stability, and fabricability of any major high-temperature alloy. It is used for combustion cans, transition ducts, flame holders, thermocouple sheaths, and other important gas turbine components.

Aerospace Alloys and Applications

HAYNES® 214® alloy

HAYNES® 214® alloy is a nickel-chromium-aluminum-iron alloy designed to provide the optimum high-temperature oxidation resistance for a wrought material, while at the same time allowing for conventional forming and joining. This alloy offers outstanding oxidation resistance to 2300°F (1260°C) and is used in demanding, specialized gas turbine parts, such as honeycomb seals combustor splash plates and other static oxidation-limited parts.

HAYNES® 242® alloy

HAYNES® 242® alloy is an age-hardenable, nickel-molybdenum-chromium alloy which derives its strength from a long-range ordering reaction upon aging. This alloy offers excellent strength to 1300°F (705°C), low thermal expansion characteristics, good oxidation resistance up to 1500°F (815°C), excellent low-cycle fatigue properties, very good thermal stability, and fabricability. It is used in gas turbine seal rings, containment, and high-strength fasteners.

HAYNES® 188 alloy

HAYNES® 188 alloy is a cobalt-nickel-chromium-tungsten alloy that offers excellent high-temperature strength and superior oxidation resistance up to 2000°F (1095°C) and thermal stability. This alloy is used extensively in demanding military and civil aircraft gas turbine engine combustors, transition ducts, and after-burner components.

HASTELLOY® X alloy

HASTELLOY® X alloy is a nickel-chromium-iron-molybdenum alloy that has been in service in aerospace applications. The alloy offers very good balance of high-temperature strength, oxidation resistance, and fabricability. This alloy is widely used for aircraft and industrial gas turbine engine fabricated combustor and exhaust components, such as transition ducts, combustor cans, spray bars and flame holders, afterburners, and tailpipes.

HAYNES® 25 alloy

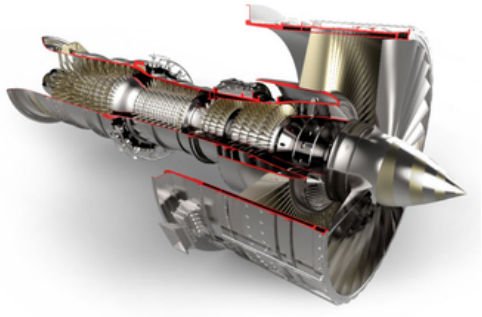
HAYNES® 25 alloy offers excellent strength, good oxidation resistance to 1800°F (980°C), and relatively good resistance to wear and galling. Used in gas turbine parts.

HAYNES® Ti-3Al-2.5V alloy

HAYNES® Ti-3Al-2.5-V alloy was developed for aircraft hydraulic and fuel systems transmission lines, primarily because of its high strength-to-weight ratio. This ratio proves to be a major advantage when used for hydraulic tubing lines to provide required strength levels, but more importantly, reducing weight by as much as 43% when compared to stainless steel.

Aerospace Applications:

- Afterburners
- Manifolds
- Hydraulic lines
- Honeycomb Seals
- Heat shields
- Exhaust ducts
- Bleed Air Systems
- Combustors
- Cases
- Rings
- Shrouds
- Fuel systems
- Fasteners



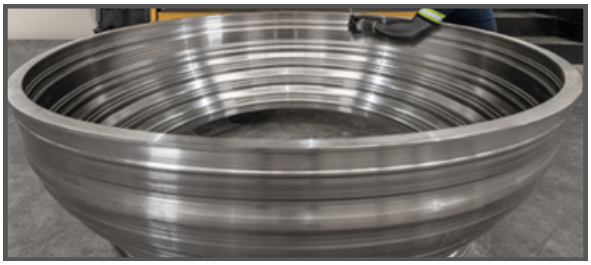
Note: A range of common aerospace alloys—including HAYNES® Waspaloy, 718, 625, X-750, 263, and R-41, 617 and HASTELLOY® S are available in various product forms. HAYNES® wire and powder products are readily available and widely used in additive manufacturing (AM) processes such as Laser Powder Bed Fusion (LPBF), Laser Powder Directed Energy Deposition (LP-DED), Wire Arc Additive Manufacturing (WAAM), and Laser Wire Directed Energy Deposition (LW-DED).

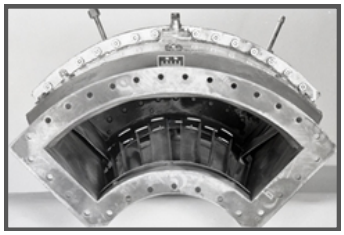
Applications for Our Alloys in Hot-section Components

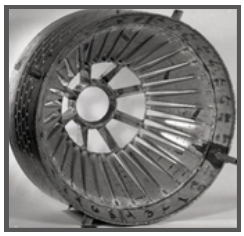
Turbine combustor liners are made include HASTELLOY® X alloy, HAYNES® 230®, 282®, and now 233® alloys, as well as 188 and 263 alloys. Turbine seal rings are made with HAYNES® 188 and HAYNES® 25 alloy. Turbine honeycomb seals are made with HAYNES® 214®, HR-224®,233®, and HASTELLOY® X alloy.

Compressor and turbine seal rings are precision-engineered components designed to minimize leakage of high-temperature pressurized gases and cooling air between rotating and stationary components. They can be made with HAYNES® 230®, 282®, 242®, 244®, 25 and 188 alloys.

Aerospace turbine cases are traditionally manufactured from HAYNES® 718 alloy, Waspaloy, and R-41 alloy. Newer alloys such as HAYNES® 282® and 292® alloys offer improved forgeability, better weldability, and simplified fabricability, combined with excellent creep resistance and improved oxidation and corrosion resistance, all are key properties for this application. Haynes International is participating in qualification trials for these turbine case components.







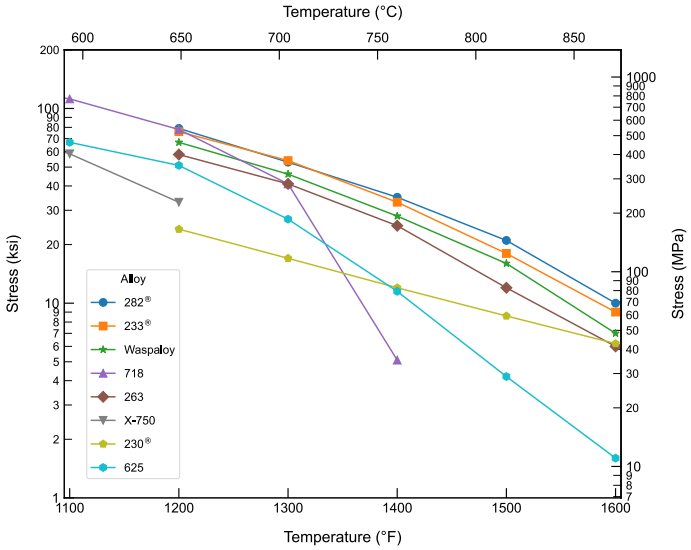
Flame holders and spreaders are hot turbine static components that require excellent oxidation resistance and superior thermal stability. Alloys for this application are HAYNES® 230®, 233®, and 617 alloys.

Turbine combustion swirlers (left image) are made with HAYNES® 230® alloy and 233® alloy. 233® is an alumina-forming precipitation strengthened alloy that is a superior alloy for these applications. Turbine exhaust cases (right image) situated in the exit hot gas path are made from HAYNES® 282® and 718 alloys.

HAYNES® 282® alloy is an industry-leading precipitation strengthened alloy used for high temperature pressurized turbine bleed ducts (left image). Jet afterburners (right image) are made with high temperature and oxidation resistant alloys such as HAYNES® 230® and 617 alloys.

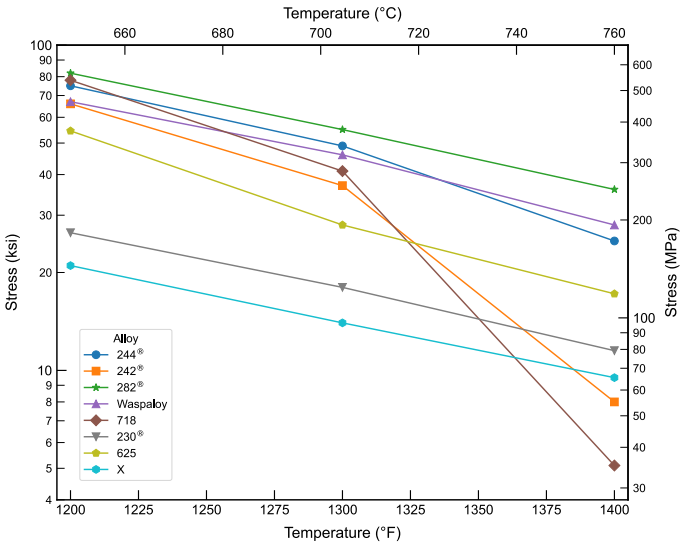
Creep Strength

1% Creep Strength – Precipitation Strengthened Alloy Sheet



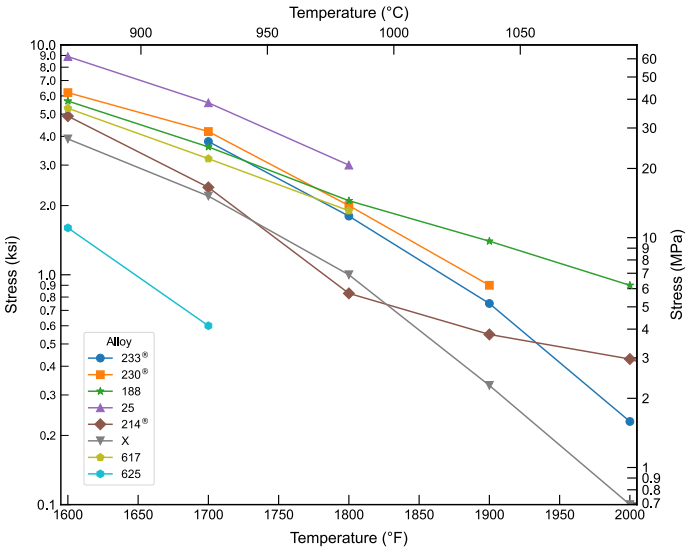
Note: 625 and HAYNES® 230® alloys are solid solution strengthened alloys.

1% Creep Strength – Low CTE, Precipitation Strengthened Alloy Plate

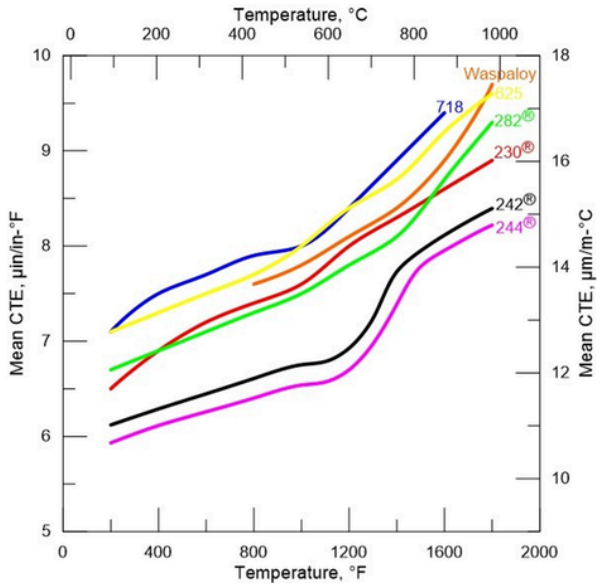


Note: 625 and HAYNES® 230® alloys are solid solution strengthened alloys.

1% Creep Properties – 1,000 hours Solid Solution Strengthened Alloy Sheet



Coefficient of Thermal Expansion



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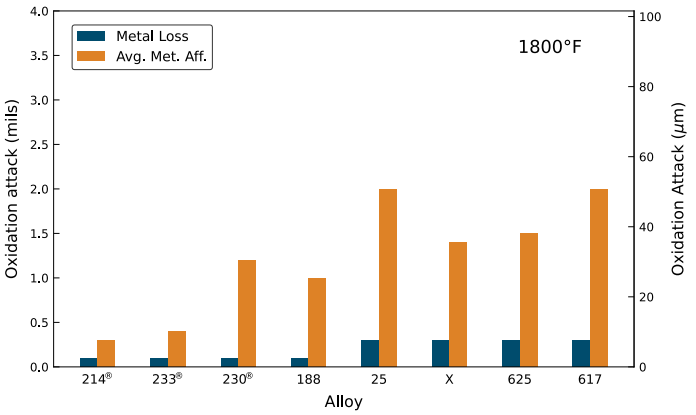
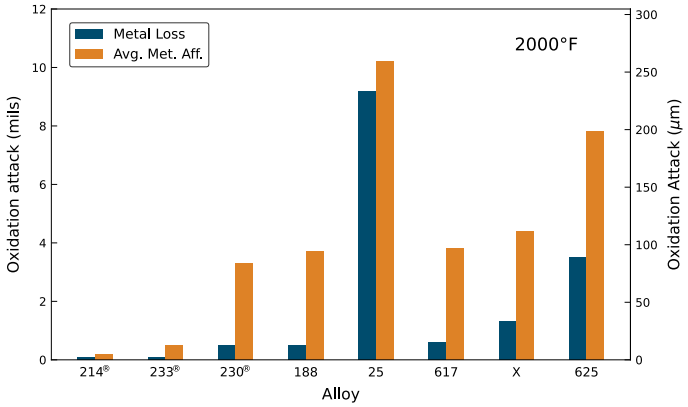
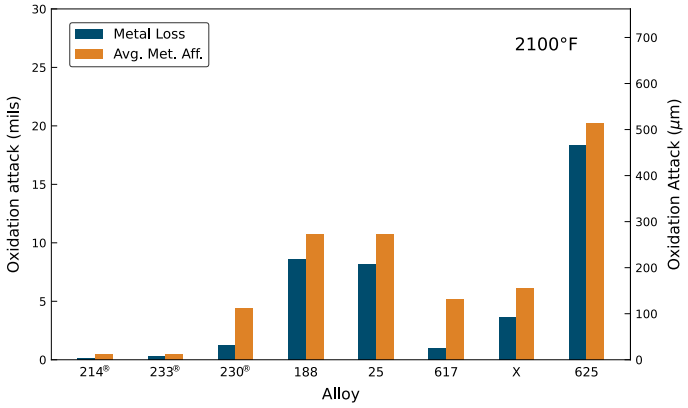
Oxidation Resistance

Static Oxidation Resistance, Air, 1008 hr
Solid Solution Strengthened Alloys

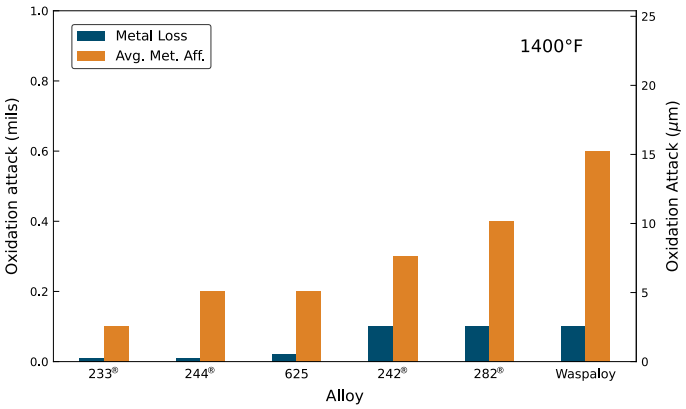


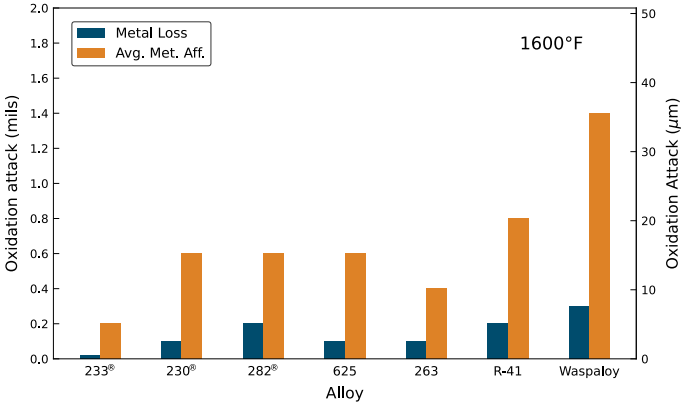




Note: Shifts in Y-axis range in charts above as temperature increases.

Static Oxidation Resistance, Air, 1008 hr
Precipitation Strengthened Alloys



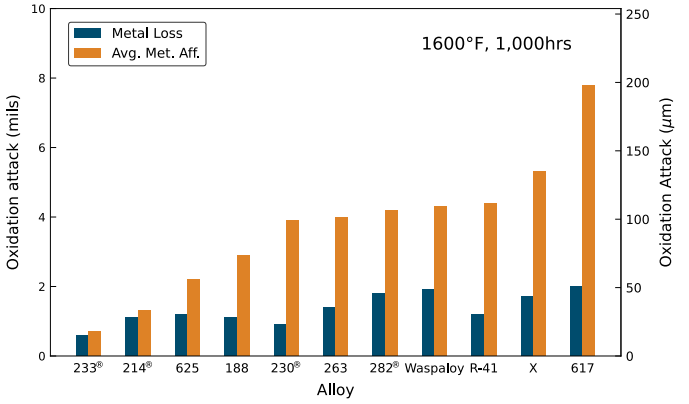


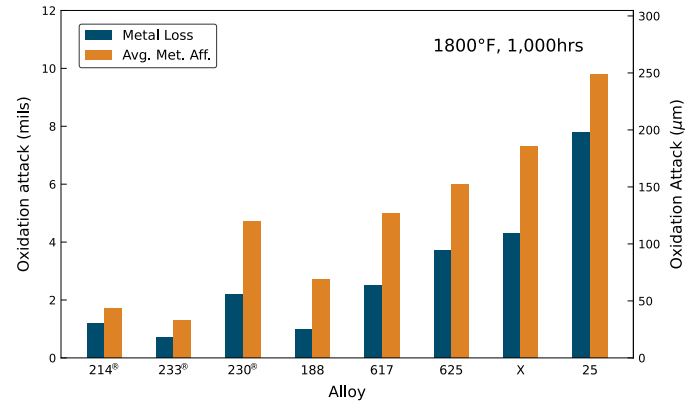
Note: Data in above charts using alloy coupons tested in the mill annealed condition. Shifts in Y-axis range in charts above as temperature increases.

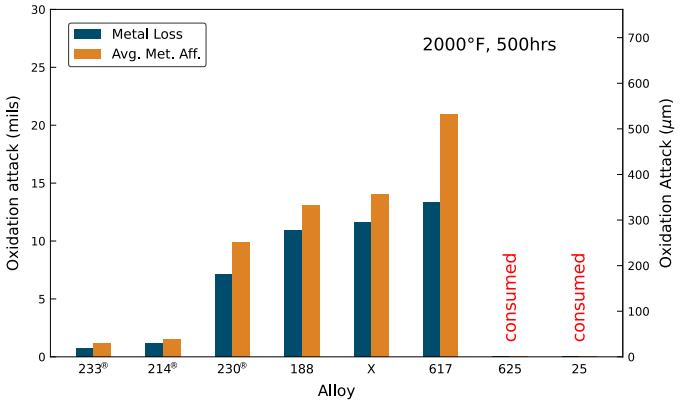
Dynamic Oxidation

Burner rig oxidation tests conducted by exposing samples in a rotating holder to combusted 2 parts No. 1 and 1 part No. 2 fuel burned in 50:1 air to fuel ratio. Gas velocity ~ 0.3 mach. Samples removed from gas stream every 30 minutes, fan-cooled to near ambient temperature and reinserted into the flame tunnel.

Dynamic Oxidation (Burner Rig) Test Data for Selected Alloys



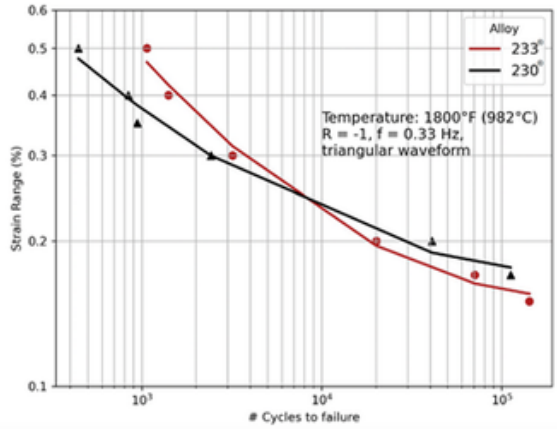




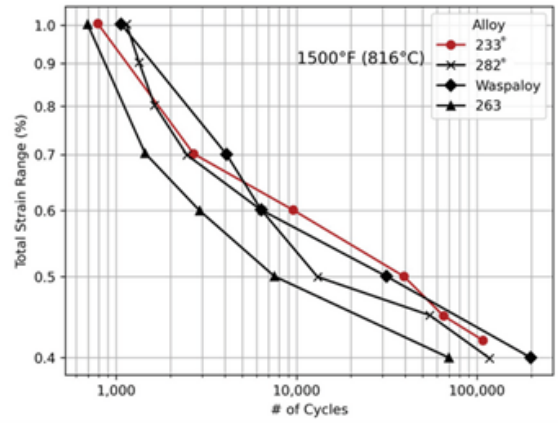
Low Cycle Fatigue (1200°F - 1600°F)

Low Cycle Fatigue - Solution Annealed

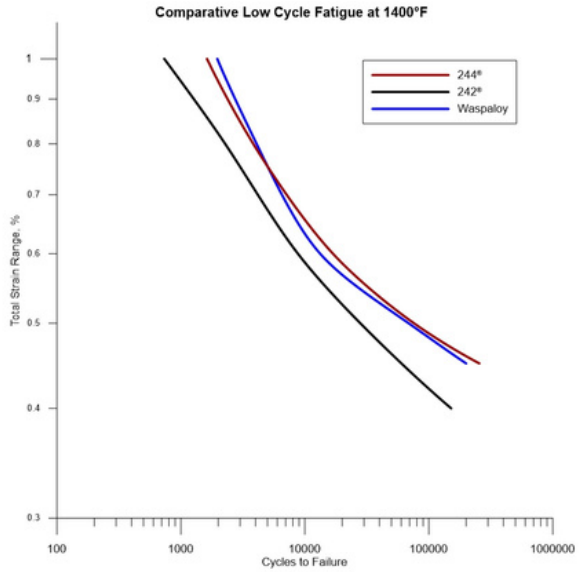
Comparative LCF: 233® vs 230® alloy [0.125 in. (3.2mm) Sheet]



Comparative Low Cycle Fatigue Data - Age hardenable



*Age-hardened (282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC, 263 allo
AC + 1550°F (845°C)/4h/AC + 1400°F (760°C)16h/AC , 233® alloy: 1650°F(899°C)/4h/



244*: Solution Annealed + Aged Hardened 1400°F / 16 h / furnace cool to 1200°F / 32 h / air cool
242*: Solution Annealed + Aged Hardened 1200°F / 24 h / air cool
Waspaloy: Solution Annealed + Aged Hardened 1825°F / 2 h / air cool to 1550°F / 4 h / air cool / 1400°F / 16 h / air cool

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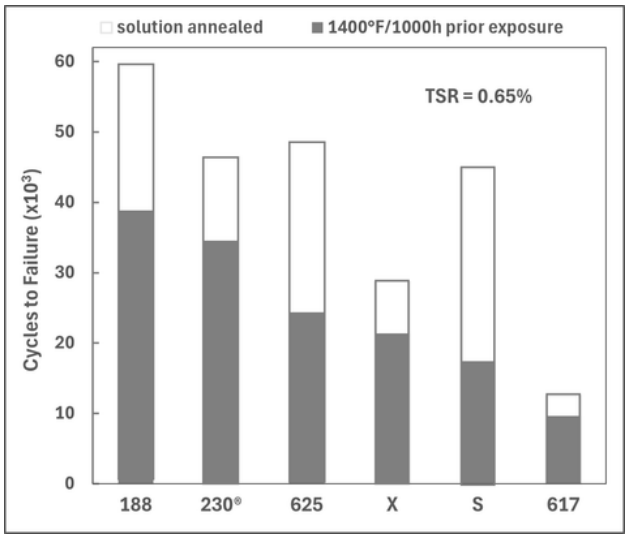
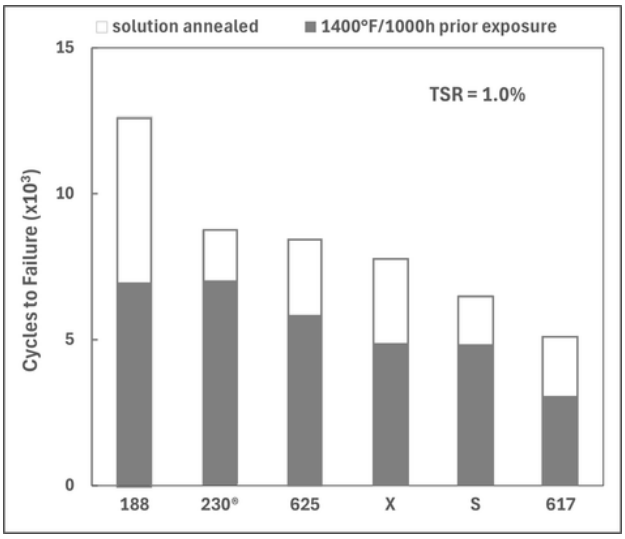
Low Cycle Fatigue (continued)

Comparative Low Cycle Fatigue Properties

The graph below shows the effect of thermal exposure on the low cycle fatigue lives of several alloys. Samples were tested at 800°F (427°C) in both the as-received and 1400°F (760°C)/1000 hour pre-exposed condition. Samples were machined from plate or bar, after exposure for exposed samples. Tests were run with fully reversed strain (R=-1) at a frequency of 20 cpm (0.33 Hz). TSR=Total Strain Range.

800°F (425°C) LCF Life for Various Alloys





Additive Manufacturing

Please inquire regarding applications, wire, and powders. Haynes has a broad range of successful additive manufacturing applications in aerospace, rockets, military, and advanced energy applications.

Turbine Exhaust Case

Swirler

Bleed Air Components

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